琉球大学学術リポジトリ

魚類における水圧情報の伝達機構の解明

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論　文　要　旨

論　文　題　目

Elucidation of the water pressure transduction in fish

Fish inhabiting shallow water adapt to the tidal environment that is repeated at an interval of 12.4 h. Their physiological and behavioral activities are possibly entrained to periodical changes in tidal cues. It is hypothesized that some fishes utilize rhythmic changes in hydrostatic pressure (HP) for spawning synchrony because some researchers have shown that the exposure of fish to HP mimicking the tidal cycle altered the syntheses of monoamines in the brain as well as steroid hormones in the ovary. However, little is known about how fishes perceive tidal cues and transduce them to the brain. The present study aimed to clarify transduction mechanisms in response to changes in water pressure in the brain of fish which were experimentally exposed to HP at 30 kPa (possible high tide stimuli in the field) or 1 kPa (low tide). When the threespot wrasse Halichoeres trimaculatus were treated with streptomycin and then exposed to HP at 30 KPa for 6 h, little change in dopaminergic activity was seen in the brain. Since this antibiotic can inhibit physiological function of superficial neuromasts and canal neuromasts in the lateral line, it is likely that water pressure is firstly perceived in this organ. Immunohistochemical analysis revealed that when the threespot wrasse was exposed to HP at 30 kPa for 2 h, Arc neurons in the optic tectum (PGZ and SWGZ) were activated. Since Arc is a marker protein showing brain activity, it is suggested that after water pressure is perceived by the lateral line, it stimulus is transduced to the optic tectum. When differentially expressed genes (DEGs) in the brain of the threespot wrasse Halichoeres trimaculatus (tropical species) and the honbera wrasse H. tenuispinis (temperate species) were verified, both of which were exposed to HP for 3 or 6 h. RNA sequencing and qPCR confirmed DEGs that were upregulated (AT atypical cadherin 2; [FAT2]) and downregulated (neuronal leucine rich repeat protein 3 [LRRN3], dual specificity tyrosine phosphorylation regulated kinase 1 [DYRK], mitogen-activated protein kinase kinase 1 [MAP2K1], and phosphoinositide 3 kinase [PI3K]). The effect of HP on the transcription of these DEGs (except for MAP2K1) disappeared within 6 h, suggesting that HP is a transitory stimulus occurring at the beginning of the tidal cycle. Similar DEG transcription was observed in the brain of honbera wrasse maintained under HP for 6 h. In situ hybridization of the brain of the threespot wrasse revealed that strong signals of MPA2K1 were seen in the telencephalon, diencephalon, and pituitary, while those of PI3K in the telencephalon, diencephalon, and medulla oblongata. This result suggests that these kinases are involved in sensory function (telencephalon), somatic and visceral function (medullar oblongata), and the neuroendocrine system (diencephalon and pituitary), all of which were related to changes in HP stimuli. Following HP exposure, the transcription of c-fos increased in the pituitary of honbera wrasse, suggesting that external stimuli directly or indirectly activate hormone synthesis at the hypothalamic-pituitary-gonadal axis. Since they are involved in the proliferation and development of neurons and mediation of hormone/neurotransmitter synthesis, HP may affect morphological changes of neurons in the central nerve system of wrasses. It is concluded that the flow of water pressure transduction is (1) water pressure is input by the neuromasts of the lateral line, (2) the detected stimulus is transduced to the optic tectum via neurons, and (3) the stimulus was processed to internal information through the expression of genes in relation to kinases, neural development, and function in the central nervous system. Through this transducing network, fish exert tidal-related behavior and physiology.

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